3D multi-resolution mapping of RSLs at Valles Marineris

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• **Recurring Slope Lineae (RSLs)** are metres- to decametres-wide dark streaks found on steep slopes, which grow during the warmest times of the year, fade during the cooler periods and reappearing again the following year.

Animated GIFs to illustrate activity of RSL features at the Newton Crater (GIF and image credits: NASA/JPL/University of Arizona)
The highest concentration of RSLs are found in **Valles Marineris**.

This research aims to study RSL features across the whole of Valles Marineris using 3D reconstruction and multi-image super-resolution restoration (SRR) from HRSC, CTX, and HiRISE images.

Animated GIFs to illustrate activity of RSL features at the Newton Crater (GIF and image credits: NASA/JPL/University of Arizona)
The CASP-GO automated DTM system

- Previously within the EU FP-7 iMars project, a fully automated multi-resolution DTM processing chain was developed, called **CASP-GO** (Co-registered ASP with Gotcha and Optimisations).

- **CASP-GO** (*Tao et al., PSS, 2018*) is based on the open source NASA Ames Stereo Pipeline, tie-point based multi-resolution image co-registration (*Tao & Muller, Icarus, 2016*), and ALSC/region growing sub-pixel refinement method (*Shin & Muller, PR, 2012*).
The CASP-GO automated DTM system

- It has the following key features:
  (a) Co-registered geo-spatial coordinates;
  (b) Improved DTM completeness;
  (c) Reduced DTM artefacts;
  (d) Improved DTM accuracy;
  (e) Uncertainty value for interpolated areas.
The CASP-GO automated DTM system

- The CASP-GO processing chain was applied to generate ~5,300 NASA MRO CTX stereo-derived 3D imaging products (~19% of the Martian surface).
- CASP-GO has also been applied to the HRSC level-2 images and is being developed for EXMTGO CaSSIS images.
Status on 3D mapping of Valles Marineris – HRSC and CTX

- HRSC level 2 images are processed to DTMs using CASP-GO, co-registered with the existing ESA DLR HRSC level 4 DTMs, and mosaiced at 50m grid spacing.
- The mosaic contains 71@50-150m DLR HRSC level 4 DTMs and 11@35m CASP-GO processed level 2 DTMs.

- 627 CTX stereo pairs have been defined and filtered for non-repeat, best resolutions, and low noise level.
- 162 of the CTX stereo pairs were processed.
- The remainder will be completed by Sep 2019.
The MAGiGAN SRR system

- Previously (UKSA CEOI SuperRes-EO 2017-2018 & OVERPaSS 2018-2019), we developed the **MAGiGAN SRR** system based on multi-angle feature restoration and deep SRR networks to produce 3-5 times resolution enhancement on repeat orbital images.
- MAGiGAN SRR can combine image information from repeat observations at various viewing angles, and retrieve information learnt from multiple imaging sources, to generate images at much higher spatial resolutions.
The MAGiGAN SRR system

Processing steps:
1. Image segmentation and shadow labelling;
2. Initial feature matching and subpixel refinement;
3. Subpixel feature densification;
4. Estimation of the image degradation models;
5. GAN network training + SRR refinement (prediction).
The MAGiGAN SRR system

**Algorithms:**

- Sub-pixel motion vectors (down to 0.01 pixel) use Mutual Shape Adapted Features ([Tao & Muller, Icarus, 2016](#)) from Accelerated Segment Test (MSA-FAST) with Convolutional Neural Network descriptors.
- Adaptive Least Squares Correlation (ALSC) and region growing (Gotcha) ([Shin & Muller, PR, 2012](#)).
- Partial Differential Equation (PDE) based Total Variation (TV) in segmented tiles for image degradation modelling ([Tao & Muller, PSS, 2016](#)).
- Generative Adversarial Network ([GAN](#)) restores high frequency texture information ([Tao & Muller, RS, 2018](#)).
SRR and 3D reconstruction applied to RSL feature tracking

- Preliminary results show linear features that are extracted from the “unmatched mask” in SRR processing.
- Note that the Shadows are automatically detected and removed from analysis.

Flow direction from steepest downward slope

- Due to the static nature of the SRR technique, we are able to restore matched (unchanged) features and meanwhile automatically track the unmatched (dynamic) pixels to characterise and measure the “change”.

- Next step is to apply deep learning techniques and slope constraints to obtain improved detection and tracking accuracy.
**Future works**

- **Plan** to apply the MAGiGAN SRR and CASP-GO DTM systems to all RSL sites in VM where repeat HiRISE images (≥5) are available, allowing statistical robustness when testing models of RSL formation.

- **Plan** to create the first regional map of RSL occurrence for VM, with associated growth rates, timings (including inter-annual variability) and topographic information (including slopes and orientation).

239 candidate/confirmed RSL sites in VM with CTX DTM and repeat HiRISE images (≥5)